Infections of dairy cattle with *Mycobacterium avium* subspecies paratuberculosis: bistability in an individual-based framework

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Mycobacterium avium subspecies *paratuberculosis* (MAP) is a endemic pathogen in dairy cattle herds worldwide. It is generally suggested that high-shedding adult animals (super-shedders) are predominately responsible for transmission events and that these high shedding adults are the main reason for endemic MAP stability in herds. However, this assumption has been challenged recently, with research demonstrating shedding among calves and experimental calf-to-calf transmission. Using ordinary differential equation (ODE) based mathematical models, we showed the a combination of early age-at-infection and a high dose-at-infection increased the probability of sustained early shedding. We then showed that this early shedding would allow MAP transmission cycles to be sustained even in the absence of high shedding adult animals, as it creates a backward bifurcation with two stable MAP prevalence equilibria under specific force-of-infection assumptions. We examined these bi-stable prevalence equilibria in [the effect of] an individual-based stochastic model (IBM) and ODE-based models which simulate transmission dynamics among age-cohorts of dairy cattle on US farms. The IBM incorporate fixed aging parameters and stochastic infection dynamics. These individual based models allow a more realistic distribution of exit from infectious states, whereas the ODE-based models rely on constant rates of exit. The herd-level outputs of ODE and individual based models were compared to the distribution of MAP herd prevalence within the US. A small portion of farms maintained a large proportion of shedding adults while the vast majority of farms show a low infection prevalence on the majority of farms.